

**REPORT ON OCEAN DUMPING R AND D
PACIFIC REGION
DEPARTMENT OF FISHERIES AND OCEANS
1986-1987**

Edited by
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RESUME

Woods, S.M. (ed.). 1988. Report on Ocean Dumping R and D Pacific Region. Department of Fisheries and Oceans, 1986-87. Can. Contract. Rep. Hydrogr. Ocean Sci. 32. 39 p.

Au cours d'un atelier de travail qui a eu lieu le 4 décembre 1987 à l'Institut des sciences océaniques, on a fait une rétrospective des recherches effectuées sur l'immersion de déchets en mer dans la Région du Pacifique (1986 - 1987). Les comptes rendus de l'atelier seront publiés sous forme de résumés développés. Les études subventionnées par le RODAC présentées à l'atelier de travail portent sur les sujets suivants: des tests de toxicité des sédiments en vue d'évaluer l'incidence de déchets immergés en mer sur les oeufs fertilisés de morue du Pacifique, l'incidence de sédiments en suspension sur les oeufs et les larves de la morue-lingue, du hareng du Pacifique et de l'éperlan argenté, une étude de l'apport en cadmium dans les sédiments de l'inlet Ucluelet (C.-B.), la mise au point et l'essai d'un véhicule autonome expérimental (le Benthic Lander) ainsi que le rassemblement et l'évaluation des données sur les recherches, le contrôle et les déversements aux sites d'immersion utilisés de 1979 à 1987 sur les côtes de la C.-B. et du Yukon. Au cours d'une expérimentation biologique menée sur des oeufs de morue du Pacifique, on a observé un taux de mortalité de 100% après 24h d'exposition à des sédiments contaminés de métaux et après 48h d'exposition à des déchets ligneux; on a démontré que le recouvrement avec des sédiments marins propres constitue une méthode efficace d'atténuation de la toxicité. Les recommandations tirées d'une étude de la toxicité des sédiments pour les premiers stades du cycle vital de la morue-lingue, du hareng du Pacifique et de l'éperlan argenté comprennent l'élaboration de bases de données sur le niveau de toxicité de sites d'immersion existants, des vérifications préliminaires de la toxicité de certains matériaux excavés excédentaires, l'utilisation du hareng du Pacifique et de l'éperlan argenté dans des essais de toxicité et l'évaluation de la qualité et de la toxicité des matériaux excavés excédentaires en fonction d'une approche plurispécifique. D'après les résultats d'une étude des sédiments de l'inlet Ucluelet (C.-B.), les apports de cadmium et de molybdène ont été attribués à la diffusion de métaux dissous dans l'eau salée surjacente dans les sédiments et leur fixation à l'état solide comme sulfure de cadmium et comme co-précipité avec le sulfure de fer, respectivement. La mise au point et les essais du Benthic Lander ont donné un modèle pratique et un protocole expérimental et on révélé que la fixation de la méiofaune sur le fond n'est pas touchée par le type de sédiments déversés au site de Point Grey. On a rassemblé et évalué des données sur les recherches, le contrôle et les déversements effectués aux sites utilisés sur les côtes de la C.-B. et du Yukon de 1979 à 1987. On

a aussi présenté les faits saillants de Seventh International Ocean Disposal Symposium qui a eu lieu à Wolfville (N.-E.). Les résultats de récentes études de pollution sur la côte ouest des Etats-Unis portent à croire que des techniques de marquage biologique et des analyses biologiques des premiers stades du cycle vital pourraient être utilisées pour étudier des questions relatives à la pollution de plus en plus complexes et importantes.

Mots-clés: immersion de déchets en mer, incidence environnementale.

ABSTRACT

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Ocean dumping research conducted in the Pacific Region during 1986-1987 was reviewed at a workshop held on 4 December 1987 at the Institute of Ocean Sciences; the proceedings have been summarized in extended abstract form for publication. RODAC-funded studies presented at the workshop include sediment toxicity tests to assess the effects of ocean-dumped materials on fertilized eggs of Pacific cod; effects of suspended sediment on eggs and larvae of lingcod, Pacific herring and surf smelt; an investigation of cadmium enrichment in the sediments of Ucluelet Inlet, B.C.; development and testing of a free-vehicle experimental platform (the Benthic Lander); and compilation and assessment of research, monitoring and dumping information for active dumpsites on the B.C. and Yukon coasts from 1979 to 1987. In a bioassay using Pacific cod eggs, 100 percent mortality occurred within 24 h with metal-contaminated sediment and 48 h with woodwaste; capping with clean marine sediment was shown to be an effective mitigative measure. Recommendations resulting from a study of sediment toxicity to early life-history stages of lingcod, Pacific herring and surf smelt included the development of toxicity data bases for established dumpsites; preliminary toxicity testing of selected dredge spoils, the use of Pacific herring and surf smelt in toxicity testing, and the evaluation of dredge-spoil quality and toxicity by a multi-species approach. As a result of an investigation of sediments from Ucluelet Inlet, B.C., cadmium and molybdenum enrichments were ascribed to the diffusion of dissolved metals from overlying seawater into the sediments and their fixation in the solid phase as cadmium sulphide and as a co-precipitate with iron sulphide, respectively. Successful development and testing of the Benthic Lander have resulted in a workable design and experimental protocol, and the indication that meiofauna settlement is not impaired by the type of sediment discharged at the Point Grey dumpsite. Research, monitoring and dumping information was compiled and assessed for active dumpsites on the B.C. and Yukon coasts from 1979 to 1987. Highlights of the Seventh International Ocean Disposal Symposium held in Wolfville, Nova Scotia were presented. Results of recent pollution studies along the west coast of the United States suggested that biomarker techniques and early-life-history bioassays may serve to address increasingly complex and severe pollution issues.

Key Words: Ocean dumping, Environmental effects.

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1. SUMMARY AND CONCLUSIONS

RODAC-funded research contracts for 1986-87 were reviewed at a workshop held on 4 December 1987 at the Institute of Ocean Sciences, Sidney, B.C. The studies included: sediment toxicity tests to assess the effects of ocean-dumped materials on fertilized eggs of Pacific cod; effects of suspended sediment on eggs and larvae of lingcod, Pacific herring and surf smelt; an investigation of cadmium enrichment in the sediments of Ucluelet Inlet, B.C.; development and testing of a free-vehicle experimental platform (the Benthic Lander); and compilation and assessment of research, monitoring and dumping information for active dumpsites on the B.C. and Yukon coasts from 1979 to 1987. Guest speakers presented some highlights of the Seventh International Ocean Disposal Symposium held in Wolfville, N.S., from 21-25 September 1987, and discussed pollution of the west coast of the United States with a perspective for the future. The discussion which concluded the workshop dealt with administration of the ODCA across Canada and concepts for proposal submissions. This report summarizes the material presented at the workshop.

In the assessment of toxicity of three commonly ocean-dumped materials on fertilized Pacific cod eggs, it was shown that metal-contaminated sediment and woodwaste caused 100 percent mortality within 24 and 48 h, respectively. Gypsum was relatively non-toxic compared to a reference sediment. Capping with clean marine sediment was shown to be an effective mitigative measure in reducing the toxicity of potentially toxic materials destined for ocean dumping.

Fertilized eggs and newly-hatched larvae of lingcod, Pacific herring and surf smelt were exposed to four concentrations of contaminated False Creek sediment and relatively uncontaminated sediment from Roberts Bank. Results of the study showed that False Creek sediment suspensions were generally more toxic to marine fish eggs and larvae than were Roberts Bank sediments. The toxic response of suspended sediments to Pacific herring and surf smelt was concentration-dependent, as egg hatchability and larval survival decreased with an increase in concentration of both test sediments. No trends in egg hatchability and larval survival between test-sediment concentrations were observed for lingcod. Relative sensitivity of early life-history stages to suspended sediment exposure were: surf smelt > Pacific herring > lingcod. Recommendations resulting from the study included the development of toxicity data bases for established dumpsites using bioassay testing with early life-history stages, preliminary toxicity testing of selected dredge spoils to determine whether they are of suitable quality for open-water disposal, the use of Pacific

herring and surf smelt in toxicity testing, and the evaluation of dredge-spoil quality and toxicity by a multi-species approach.

An investigation of cadmium enrichment in the sediments of Ucluelet Inlet, B.C. indicated that cadmium concentrations were unusually high compared to most marine environments and also correlated significantly in depth profiles with molybdenum and organic carbon. The sedimentation rate was about an order of magnitude less than is found in typical B.C. fjords. Lead and cobalt were enriched in surface sediments, possibly due to a recent input of metal-rich sediments from Thornton Creek. Organic carbon concentrations in the sediments were high. The absence of manganese enrichment coupled with the presence of hydrogen sulphide in surface sediments suggested that the deposits were anoxic very near the sediment-water interface. Cadmium and molybdenum enrichments were ascribed to the diffusion of dissolved metals from overlying seawater into the sediments and their fixation in the solid phase as cadmium sulphide and as a coprecipitate with iron sulphide, respectively. It was concluded that further study through high-resolution, pore-water sampling and analysis is required.

During 1986, the first year of the Benthic Lander project, most attention was directed to the development and refinement of the prototype experimental platform. Field work during 1987 included two full-scale colonization experiments as well as a final wild ecosystem survey. The successful outcome of the deployments indicated that a workable design and experimental protocol had been achieved. Biological analyses showed that colonization occurred in both sediment types at all Lander locations and that there were no significant differences between colonization rates by sediment type or Lander location. The dominant colonists were harpacticoid copepods, nematodes and polychaetes. The expectations that heavy-metal contamination would occur during handling and that exposure at the dumpsite would elevate heavy-metal concentrations were not realized.

Research, monitoring and dumping information was compiled and assessed for active dumpsites on the British Columbia and Yukon coasts from 1979 to 1987. This catalogue is a continuation of a previous report prepared for the Pacific region.

The Seventh International Ocean Disposal Symposium held in Wolfville, Nova Scotia, was divided into eight sessions: industrial waste and sewage sludge in the oceans; ocean outfalls; dredged-material disposal; management of wastes in the ocean; pathways and fates of wastes in marine environments; biological effects; incineration at sea; and risk assessment in marine waste management. Topics discussed by guest speakers included

ocean disposal in Canada; overview of the interagency testing of dredged material Field Verification Program; environmental acceptability of ocean incineration emissions, with some remarks on future research and regulations; decision-making framework for dredged-material management; use of sediments to predict dispersal of contaminants; and justification of sea disposal of wastes. Highlights of the symposium were presented at the workshop.

Recent pollution studies along the west coast of the United States revealed significantly different proportions of a variety of toxic chemicals in sediments, and pathological conditions in fish associated with exposure to such toxicants. However, while data may suggest possible cause/effect relationships between chemical exposures and biological effects, they fail to actually establish such relationships. This deficiency, combined with the increasing criticism of the effectiveness of acute bioassays, severely hampers the assessment of environmental damage from low levels of toxic chemicals in sediment and water. In order to address the increasingly complex and severe pollution issues, it was suggested that use of biomarker techniques involving the assessment of "DNA damage", and bioassays that focus on the life cycles of key ecosystem components are steps in the right direction.

The workshop ended with a discussion that included a review of the ODCA research programme nationally. This year the number of proposal submissions from the Atlantic Region was significantly higher than from the Pacific Region (32 and 6, respectively). It was suggested that the shallower water depths encountered on the east coast may facilitate research projects, as compared with the relatively deeper dumpsite locations on the Pacific coast. Possible study topics recommended for the Pacific Region include biological testing, physical transport studies, dumpsite assessments, development of a quality assurance/quality control protocol and review of scheduled substances with regard to permit levels.

Extended abstracts of the RODAC studies contracted in 1986-87 are contained in this report. Inquiries regarding the information presented and further publications should be directed to the appropriate scientific authorities at their associated institutes. Appendix I lists the abbreviations and addresses of these institutes.

A list of those who attended the workshop is contained in Appendix II. Appendix III outlines contracts for 1986-87, while studies contracted for 1987-88 are listed in Appendix IV.

Copies of this Canadian Report of Hydrography and Ocean Sciences are available from the Institute of Ocean Sciences, Sidney, B.C.

This report was prepared by S.M. Woods Consulting under contract to the Institute of Ocean Sciences (Ref. SSC File No. 06SB.FP941-7-7142).

2. SEDIMENT TOXICITY TESTS TO ASSESS THE EFFECTS OF OCEAN-DUMPED MATERIALS ON FERTILIZED EGGS OF PACIFIC COD (Gadus macrocephalus)

E.R. McGreer and M.E. Annand

Contractor: COASTLINE Environmental Services Limited
Scientific Authority: M. Waldichuk, DFO West Vancouver

The toxicity of three different types of commonly ocean-dumped materials was assessed using fertilized eggs of Pacific cod (Gadus macrocephalus). The test materials were woodwaste, metal-contaminated sediment and gypsum. The effectiveness of "capping" with different thicknesses of clean marine sediment in reducing toxicity was also evaluated.

Metal-contaminated sediment and woodwaste were most toxic, resulting in 100 percent mortality within 24 h and 48 h respectively. Capping with either 1 cm or 8 cm of clean sediment significantly reduced toxicity of both the metal-contaminated sediment and the woodwaste. After 120 h exposure, egg survival was higher in test containers with an 8-cm cap compared to a 1-cm cap. Gypsum was relatively non-toxic compared to the Reference sediment. Capping was shown to be an effective mitigative measure in reducing the toxicity of potentially toxic materials for ocean dumping.

3. EFFECTS OF SUSPENDED SEDIMENT ON EGGS AND LARVAE OF LINGCOD (Ophiodon elongatus), PACIFIC HERRING (Clupea harengus pallasii), AND SURF SMELT (Hypomesus pretiosus)

J.D. Morgan

Contractor: E.V.S. Consultants Limited

Scientific Authority: C.D. Levings, DFO West Vancouver

Fertilized eggs and newly-hatched larvae of lingcod (Ophiodon elongatus), Pacific herring (Clupea harengus pallasii) and surf smelt (Hypomesus pretiosus) were exposed to four concentrations (0, 0.5, 4 and 10 g/L) of a contaminated (False Creek) and relatively uncontaminated (Roberts Bank) marine sediment. Each bioassay test was conducted with the sediments kept in suspension by constant aeration. Effects measured included egg mortality during development, timing of development, percent hatchability, and larval survival after hatching.

Chemical analyses showed that False Creek sediments contained higher levels of contaminants than did Roberts Bank sediments, and that the test sediments could therefore be classified as being relatively contaminated and uncontaminated, respectively. Exposure of fertilized herring and surf smelt eggs to False Creek sediment suspensions resulted in lower hatching success than did exposure to Roberts Bank sediments at similar concentrations (Figures 1 and 2). Differences in hatching success of eyed lingcod eggs between the test sediments were not significant (Figure 3). Premature hatching of lingcod eggs was observed at higher concentrations of both test sediments, while hatching of herring eggs was delayed at 10 g/L of False Creek sediment (Tables 1 and 2). Survival of newly-hatched lingcod, herring and surf smelt larvae to yolk-sac exhaustion was higher in Roberts Bank sediments than in False Creek sediment suspensions (Tables 3-5). Larvae of all three species were more sensitive to suspended-sediment exposure than was the egg stage.

Results of the study showed, therefore, that False Creek sediment suspensions were generally more toxic to marine fish eggs and larvae than Roberts Bank sediments, which was consistent with the higher level of chemical contaminants found in the False Creek sediments. The toxic response of Pacific herring and surf smelt to suspended sediments was concentration-dependent, as egg hatchability and larval survival decreased with an increase in concentration of both test sediments. Trends in egg hatchability and larval survival between concentrations of test sediment were not observed for lingcod. Early life-history stages of the surf smelt were the most sensitive to suspended sediment exposure, followed by Pacific herring and lingcod, respectively.

Based on the results of the present study, the following recommendations for future research were made:

- Bioassay testing of bottom sediments at the Point Grey and Quarantine Buoy Dumpsites should be carried out using early life-history stages of marine fish species to develop a toxicity data base for these established dumpsites.
- Preliminary toxicity testing of selected dredge spoils designated for ocean dumping should be conducted and compared to the disposal-site data to determine whether the dredge spoils are of suitable quality for open-water disposal. Decisions regarding sediment quality should be made in conjunction with established ODCA chemical criteria.
- Species recommended for use in toxicity testing of dredge spoils are Pacific herring in the spring and surf smelt during the summer and fall periods. Further research should be conducted to improve the laboratory culture of surf smelt. Since surf smelt eggs are readily available in the Vancouver area almost year-round, consideration should be given to developing the surf smelt as an indicator species for routine toxicity testing of dredged sediments.
- A multi-species approach to toxicity testing should be considered to evaluate the quality of dredge spoils and the possible effects on several trophic levels (e.g., amphipods, bivalve larvae, fish eggs and larvae, etc.).

TABLE 3.1

Time (in days) to 5, 50 and 95% hatch of
eyed lingcod eggs exposed to Roberts Bank
and False Creek Sediments.

Sediment	Conc. (g/L)	Time (d) to Hatch ^a		
		5%	50%	95%
Roberts Bank	10	18	19.5	23
	4	19.5	20.5	30
	0.5	18.5	21	28
False Creek	10	18.5	20	26.5
	4	19.5	21	26
	0.5	20	21.5	27
Control	0	20	21	31.5

^aMean of two replicates

TABLE 3.2

Time (in days) to 5, 50 and 95% hatch of
herring eggs exposed to Roberts Bank
and False Creek sediments.

Sediment	Conc. (g/L)	Time (d) to Hatch ^a		
		5%	50%	95%
Roberts Bank	10	10	10	11.5
	4	10	10	12.5
	0.5	10	10.5	11.5
False Creek	10	10	12.5	14.5
	4	10	10.5	12.5
	0.5	10	10	11.5
Control	0	10	11	11.5

^aMean of two replicates

TABLE 3.3

Survival of lingcod larvae after 10-day exposure to Roberts Bank and False Creek sediments.

Sediment	Conc. (g/L)	Rep.	Total Larvae	10-d Survival No.	10-d Survival %	Mean Survival (%)
Roberts Bank	10	A	287	29	10	8
		B	301	21	7	
	4	A	42	6	14	4
		B	238	4	2	
	0.5	A	179	20	11	10
		B	126	10	8	
False Creek	10	A	343	27	8	7
		B	192	13	7	
	4	A	355	8	2	2
		B	388	8	2	
	0.5	A	313	14	5	6
		B	252	22	9	
Control	0	A	119	104	87	82
		B	43	28	65	

TABLE 3.4

Survival of herring larvae after 4-day exposure to Roberts Bank and False Creek sediments.

Sediment	Conc. (g/L)	Rep.	Total Larvae	4-d Survival No.	4-d Survival %	Mean Survival (%)
Roberts Bank	10	A	224	1	0.4	0.3
		B	75	0	0.0	
	4	A	162	3	1.9	5.5
		B	332	24	7.2	
	0.5	A	202	33	16.3	9.8
		B	175	4	2.3	
False Creek	10	A	142	1	0.7	0.4
		B	134	0	0.0	
	4	A	190	1	0.5	0.7
		B	120	1	0.8	
	0.5	A	307	1	0.3	0.6
		B	211	2	1.0	
Control	0	A	317	233	73.5	76.4
		B	217	175	80.5	

TABLE 3.5

Survival of surf smelt larvae after 7-day exposure
to Roberts Bank and False Creek sediments.

Sediment	Conc. (g/L)	Rep.	Total Larvae	7-d Survival No.	Survival %	Mean Survival (%)
Roberts Bank	10	A	1	0	0.0	0.0
		B	2	0	0.0	
	4	A	1	0	0.0	0.0
	0.5	A	6	3	50.0	42.9
		B	1	0	0.0	
False Creek	4	A	1	0	0.0	0.0
		B	1	0	0.0	
	0.5	A	1	0	0.0	0.0
		B	1	0	0.0	
Control	0	A	23	7	30.4	41.1
		B	33	16	48.5	

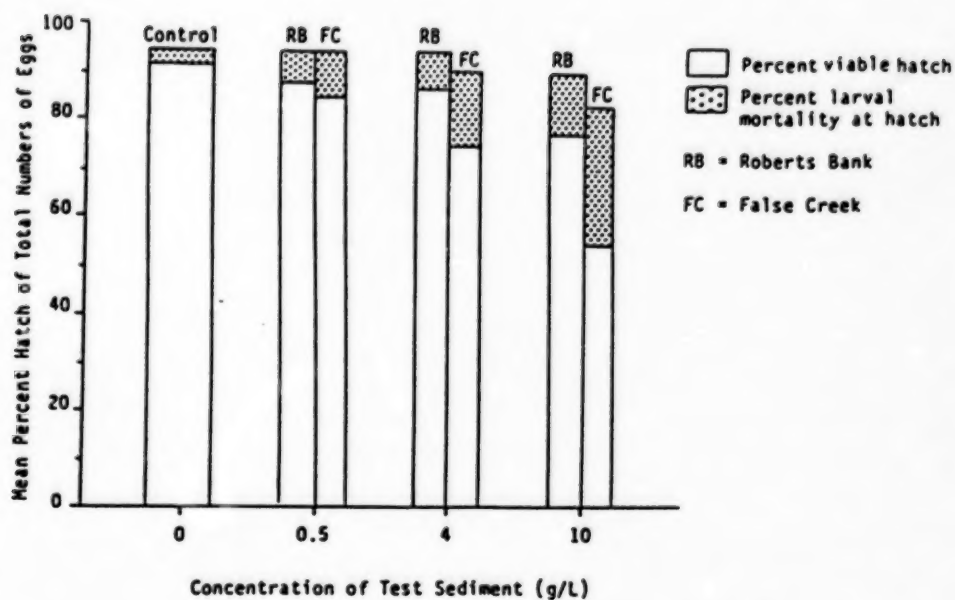


FIGURE 3.1. Mean percent hatch of herring eggs in various concentrations of suspended Roberts Bank and False Creek sediments.

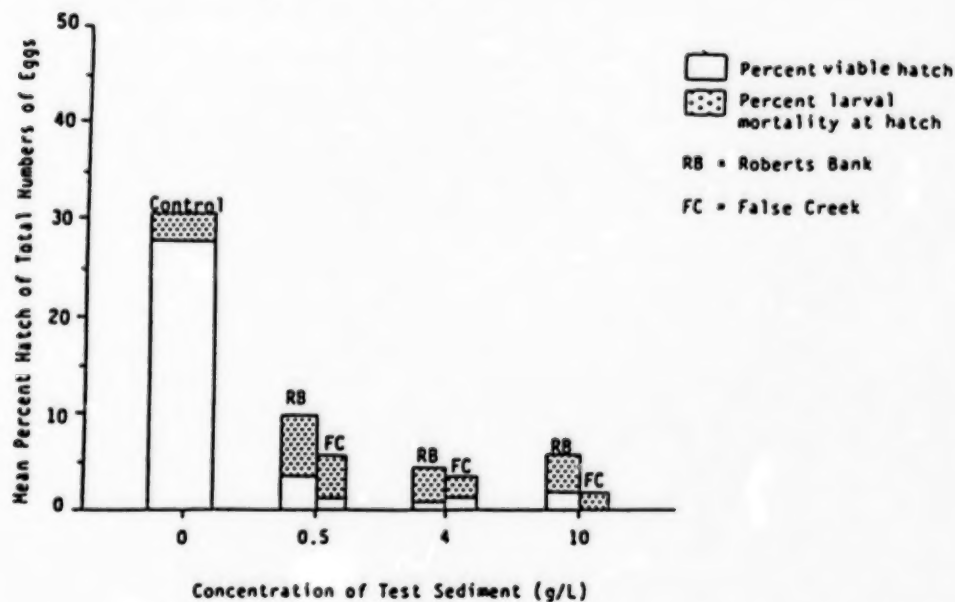


FIGURE 3.2 Mean percent hatch of surf smelt eggs in various concentrations of suspended Roberts Bank and False Creek sediments.

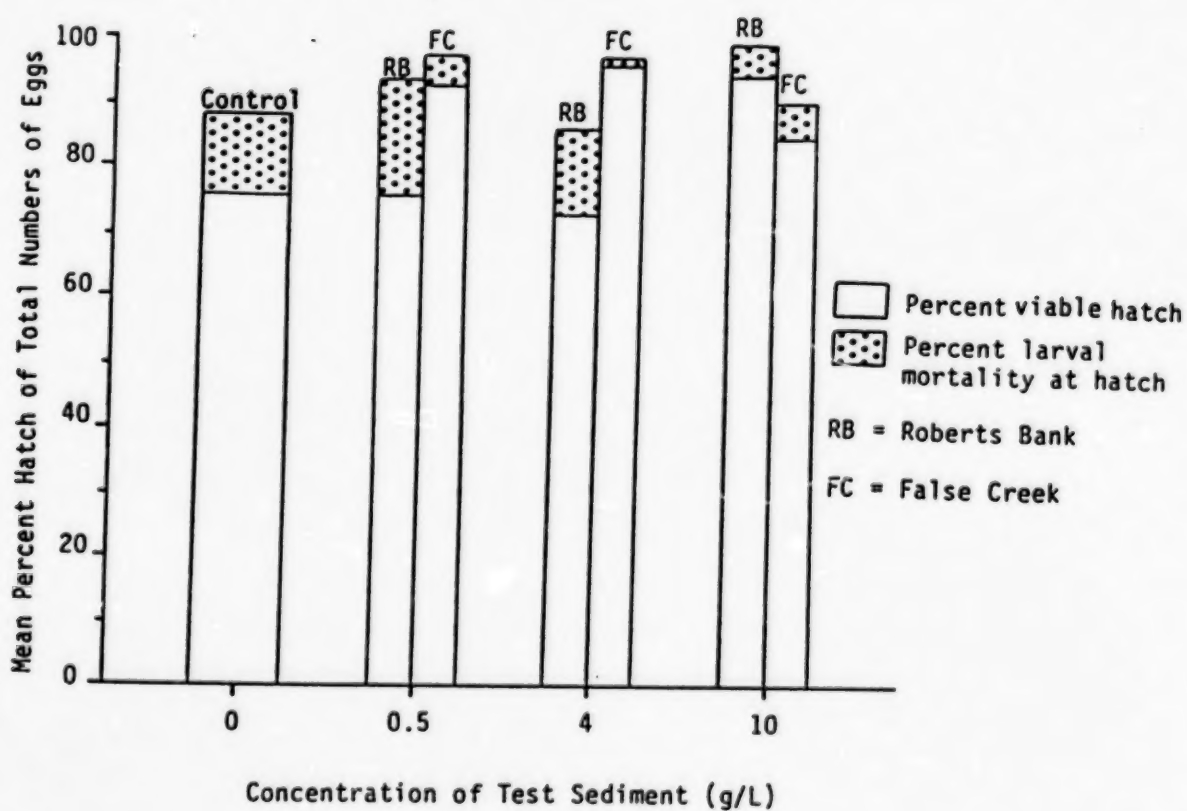


FIGURE 3.3 Mean percent hatch of eyed lingcod eggs in various concentrations of suspended Roberts Bank and False Creek sediments.

4. AN INVESTIGATION OF CADMIUM ENRICHMENT IN THE SEDIMENTS OF UCLUELET INLET, BRITISH COLUMBIA.

T.F. Pedersen and R.D. Waters

Contractor: R. Waters, Environmental Consultant
Scientific Authority: H. Nelson, EPS West Vancouver

The purpose of this study was to examine the distribution and potential sources of cadmium (Cd) in Ucluelet Inlet and to consider possible mechanisms for concentration of the element in the sediments. The phenomenon of metal enrichment in apparently undeveloped areas to levels which exceed existing ODCA criteria is important to regulatory agencies and proponents of dredging programmes alike; the understanding of such phenomena may provide insight into natural processes and their relevance to the management of dredge spoil in the marine environment.

In this report, we focused on the chemical composition of a limited suite of cores collected from the inlet in concert with high-resolution sedimentation-rate measurements. The chemical assessment included determination of the concentrations of a broad range of major and minor elements, including Cd, as well as organic and carbonate carbon and total nitrogen measurements, to allow a reasonably comprehensive interpretation of the geochemical nature of the sediments. The study included consideration of potentially influential geochemical factors such as textural heterogeneity, the presence of oxide and/or sulphide phases, and the proportions of terrigenous versus more reactive marine organic matter. Based on these myriad influences and the presence or absence of correlations between several of the compositional parameters, we propose a mechanism which plausibly explains the Cd enrichment in Ucluelet Inlet sediments as a natural phenomenon related to the unique sedimentary characteristics of the basin.

We confirmed in this report that cadmium concentrations in Ucluelet Inlet sediments are unusually high compared to most marine environments. In addition, they correlate significantly in depth profiles with molybdenum (Mo) and organic carbon at the sites investigated. Neither metal was detected at elevated levels in the stream sediment samples collected from the major creeks tributary to the inlet.

The following statements summarize the essential findings:

- 210Pb (lead) data indicate that the sedimentation rate in the central basin of the inlet is very low, ranging from about 0.07 to 0.36 cm per year. These rates are about an order of magnitude less than is found in typical B.C. fjords; Ucluelet Inlet thus appears to be a starved basin.

- Pb and Co (cobalt) are enriched in surface sediments, possibly because of a recent input of metal-rich sediments from Thornton Creek. A single stream sediment sample contained high concentrations of Pb, Co and As (arsenic). Part of the surficial Pb signal may also represent anthropogenic lead delivered to the inlet by atmospheric pathways.
- Organic carbon concentrations in the sediments are high. Carbon:nitrogen-ratio data indicate a mixed terrigenous/marine provenience for the organic material and a relatively recent increase in the terrigenous portion which we believe represents wood debris associated with logging and booming activities in the area.
- The absence of Mn (manganese) enrichment in the surface sediments, coupled with qualitative observations that H_2S (hydrogen sulphide) is present at very shallow depths, strongly suggests that the deposits are anoxic very near the sediment-water interface.
- Rather than being due to anthropogenic inputs, the Cd and Mo enrichments are ascribed to diffusion of the dissolved metals from overlying seawater into the sediments and their fixation in the solid phase as CdS (cadmium sulphide) and as a coprecipitate with FeS (iron sulphide), respectively. Comparison of the sedimentary accumulation rate of Cd with the diffusive flux theoretically necessary to supply the Cd to the solid phase Cd suggests that the diffusion-fixation hypothesis is plausible.
- In order to generate a more refined explanation of the Cd enrichment in Ucluelet Inlet sediments, high-resolution pore-water sampling and analysis are required.

5. DEVELOPMENT AND TESTING OF THE BENTHIC LANDER, A FREE-VEHICLE EXPERIMENTAL PLATFORM FOR STUDYING THE ENVIRONMENTAL EFFECTS OF OCEAN DUMPING: PROGRESS REPORT 2.

E.P. Anderson

Contractor: Edward Anderson Marine Sciences
Scientific Authority: C.D. Levings, DFO West Vancouver

OBJECTIVES

At present, assessment of environmental disturbances in deep water is largely performed by taking static "snapshots" of sediment characteristics and benthic community structure. The Benthic Lander project will provide an economical and efficient means to determine the mechanisms and rates of processes which lead to observed benthic community structure at ocean dumpsites and other areas which, because of depth or other hazard, are beyond ordinary access by SCUBA.

The primary objective of the project, that of developing the Benthic Lander concept into a practical device with experimental demonstration, has been largely met, and was reported in Progress Report 1 (Anderson, 1987). The secondary objective was to refine the device and experimental protocol for determining rates of benthic colonization under various field conditions during an experiment at the Point Grey dumpsite. The study area lies at a depth of about 250 m in the Strait of Georgia near Vancouver, B.C. (Figure 1). We performed two Benthic Lander experiments. These are reported here, together with chemical and partial biological results. A final progress report will be delivered in 1988.

SUMMARY OF PROGRESS REPORT 1

During the first year of this project, we directed most attention to the development and refinement of the Benthic Lander. We made two prototype deployments in Saanich Inlet and one full-scale experiment at the Point Grey dumpsite. The Lander evolved significantly as a result of these field experiences.

REFINEMENT OF BENTHIC LANDER DESIGN

The Benthic Lander in its present form resembles Figures 1-2 of Anderson (1987). The device is a fibreglass box 60 cm square and 17.5 cm deep, ballasted below with three 45-kg steel plates. Two of the plates are free to slide vertically about 10 cm. The sliding ballast operates a linkage which opens two clear Lexan plastic doors on the upper side of the Lander. The doors are open when the Lander rests on bottom or on deck, but closed when

the Lander is suspended during deployment or recovery. At the end of each experiment, the Lander releases a buoy which carries a recovery line to the surface. Refinements have included redesign of the door-closure mechanism, replacement of many custom fabricated parts by standard commercial products, and replacement of metal by plastic elements. Because experimentation at an active dumpsite will always entail some risk, we have designed for affordable loss.

FIELD WORK IN 1987

We performed two full-scale Benthic Lander colonization experiments plus a final wild ecosystem survey in 1987. Table 1 shows the dates, objectives and outcomes of all field work in the programme.

In the first 1987 experiment (PG2 plus SI3), we deployed three Landers, each of which carried both dumpsite and natural reference sediments which had been defaunated by freezing. One Lander was placed in the northern quadrant of the dumpsite, the second at a reference station three nautical miles west of dumpsite centre, and the third at a remote reference station in Saanich Inlet. The experiments proceeded from 23 May to 3 June and were a complete operational success. The exposure times were shorter than intended because the galvanic releases, represented as 30-day devices by the manufacturer, in fact let go at a predictable 10 days in our application.

Because the second experiment was so successful, we sought to confirm its results. The third full-scale experiment (PG3) proceeded from 21 through 31 July. Its design was a repeat of PG2. During both experiments, there was light-to-moderate dumping activity. A light scattering of sand, gravel and woodwaste was evident over the entire surface of both dumpsite Landers. In addition to the dumped material, there was a very thin (est. 1 mm) flocculent deposit over the entire surface of all Lander sediments. This was probably riverine silt plus the re-established oxidized layer of normal sediments.

RESULTS

At the time of this report, biological analyses are in progress. Colonization did occur in both sediment types at all Lander locations. The dominant colonists were harpacticoid copepods, nematodes and polychaetes. At the taxonomic class level of analysis, there were no significant differences between colonization rates by sediment type or Lander location. Heavy-metal analyses, which are complete, are summarized here.

Figure 2 shows the pattern of heavy-metal concentrations in sediments of the wild ecosystem, in terms of averages and deviations from average. Most of the gross pattern is as expected: positive deviations are clustered mainly about the dumpsite, and the highest proportion of negative deviations is found at the stations most influenced by river silt. Station N3 shows an unexpected dominance of positive deviations. This may be attributable in part to the higher proportion of fine-grained sediment at stations remote from the dumpsite and river, and in part to coastal industrial sources.

Tables 2 and 3 present heavy-metal results for the two complete Benthic Lander experiments. One aspect of the data confirms results from the wild ecosystem survey: Station N3, which was the source of reference sediment, had higher copper (Cu) and zinc (Zn) than did sediment from the dumpsite. Lead (Pb) was higher at the dumpsite, and cadmium (Cd) about equal in the two sediment types, at the beginning of each experiment.

Exposure of these sediments to ocean-bottom conditions produced an expected result. There was a general decline in all heavy metals at all stations, and in both experiments. Also, we had feared contamination during handling, and expected that exposure at the dumpsite would elevate heavy-metal concentrations; both expectations were proven false.

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TABLE 5.1. Summary of cruises: wild ecosystem sampling and Benthic Lander experiments.

EXPERIMENT	DATES	PURPOSE	RESULTS
1986			
SI1B 14	Feb.	Prototype test.	Lander fouled by recovery system. Redesign with intermediate float.
SI1E 25	Feb.		
PG1B 21-26	Feb.	Test revisions. Full-scale expt.	One Lander damaged in test. Two deployed at Pt. Grey. Wild ecosystem sampling.
PG1E 6-8	May	Recover.	Not up; echosound contact.
14	May	Aerial search.	Not up.
21-22	May	Echosound.	In place, not up.
6-7	June	Recover.	One Lander recovered normally but part of experiment washed out: fouled recovery system? Grapple for second, fail. Redesign mooring and recovery system. Abandon second Lander.
8	Sep.	Grapple again.	
SI2B 19	Oct.	Test new mooring.	Lander and recovery system now operate successfully.
SI2E 2	Dec.	Compare freezing and boiling defaunation.	Defaunation results similar.
1987			
PG2B 21-23	May	Second full-scale transposition expt.	Operation completely successful. Sediments recovered undisturbed.
PG2E 3	June	Compare site and sed type effects.	Major chemical result was loss of heavy metals through exposure. No decrease in colonization attributable to sediment or location.
SI3B 27	May	Extend expt PG2	
SI3E 9	June	to remote reference area.	
PG3B 20-21	July	Repeat PG2.	Complete operational success. Chemical result confirmed. Biology available Feb. 1988.
PG3E 29-31	July		

TABLE 5.2. Heavy-metal concentration in Benthic Lander sediments, experiments PG2/SI3. Raw data are followed by average change over the 10-day exposures, grouped by experimental sediment type and place of exposure.

LANDER LOCATION SEDIMENT SOURCE	HEAVY METALS IN SEDIMENTS				
	(ug/g dry weight) (Corrected for % recovery)				
	Cd	Cu	Pb	Zn	Hg
BEGIN [22-23 May, 27 May (SI3)]					
N 0.5 (LDR 1)					
C,N 3.0	.18	59.8	20.6	130.1	.117
DS, NE 0.5	.21	43.6	31.6	110.0	.080
W 3.0 (LDR 2)					
C	.17	62.4	23.4	134.8	.129
DS	.21	46.4	49.5	110.1	.090
Mill Bay (LDR3, Average values for LDR1, LDR2)					
C	.18	61.1	22.0	132.5	.123
DS	.21	45.0	40.6	110.0	.085
END [3 June, 9 June (SI3)]					
N 0.5 (LDR 1)					
C	.18	55.9	19.3	120.8	.107
DS	.18	40.0	31.6	99.9	.076
W 3.0 (LDR 2)					
C	.18	55.2	17.9	125.4	.081
DS	.20	32.7	26.0	92.2	.084
Mill Bay (LDR 3)					
C	.16	54.7	17.9	123.1	.102
DS	.24	41.8	27.5	113.1	.075

CHANGE DURING EXPERIMENT

END-BEGIN (BY LANDER LOCATION)					
N 0.5	-.01	-3.7	-.7	-9.7	-.007
W3	-.00	-10.4	-14.5	-13.6	-.027
Mill Bay	.01	-4.8	-8.6	-3.1	-.016
END-BEGIN (BY SEDIMENT SOURCE)					
C	-.00	-5.8	-3.7	-9.4	-.03
D	-.00	-6.8	-12.2	-8.3	-.01

TABLE 5.3. Heavy-metal concentrations in Benthic Lander sediments, experiments PG3.

LANDER LOCATION SEDIMENT SOURCE		HEAVY METALS IN SEDIMENTS (ug/g dry weight) (Corrected for % recovery)				
		Cd	Cu	Pb	Zn	Hg
BEGIN (21 July 87)						
	N 0.5 (LDR 2)					
	C	.18	62.3	26.6	135.4	.144
	DS	.24	41.5	36.0	120.3	.082
	W 3.0 (LDR 1)					
	C	.21	60.6	20.4	126.9	.204
	DS	.19	41.9	45.4	104.0	.087
END (31 July 87)						
	N 0.5 (LDR 1)					
	C	.17	59.1	21.9	126.9	.126
	DS	.20	35.9	47.0	105.4	.075
	W 3.0 (LDR 2)					
	C	.13	55.4	21.9	126.9	.124
	DS	.15	42.3	25.0	99.8	.072

CHANGE DURING EXPERIMENT

END-BEGIN (GROUPED BY LANDER LOCATION)

N 0.5	ave	-.02	-4.4	3.1	-11.7	-.012
W3		-.06	-2.4	-9.4	-2.1	-.048

END-BEGIN (BY SEDIMENT SOURCE)

C	ave	-.04	-4.2	-1.6	-4.2	-.05
D	ave	-.04	-2.6	-4.7	-9.5	-.01

REFERENCE STATION SAMPLES

N3		.16	40.0	13.0	95.1	.095
W3		.11	37.8	13.0	101.0	.099
NE 0.5		.32	24.1	6.0	64.2	.055
NW 0.5		.19	37.5	35.0	90.1	.077

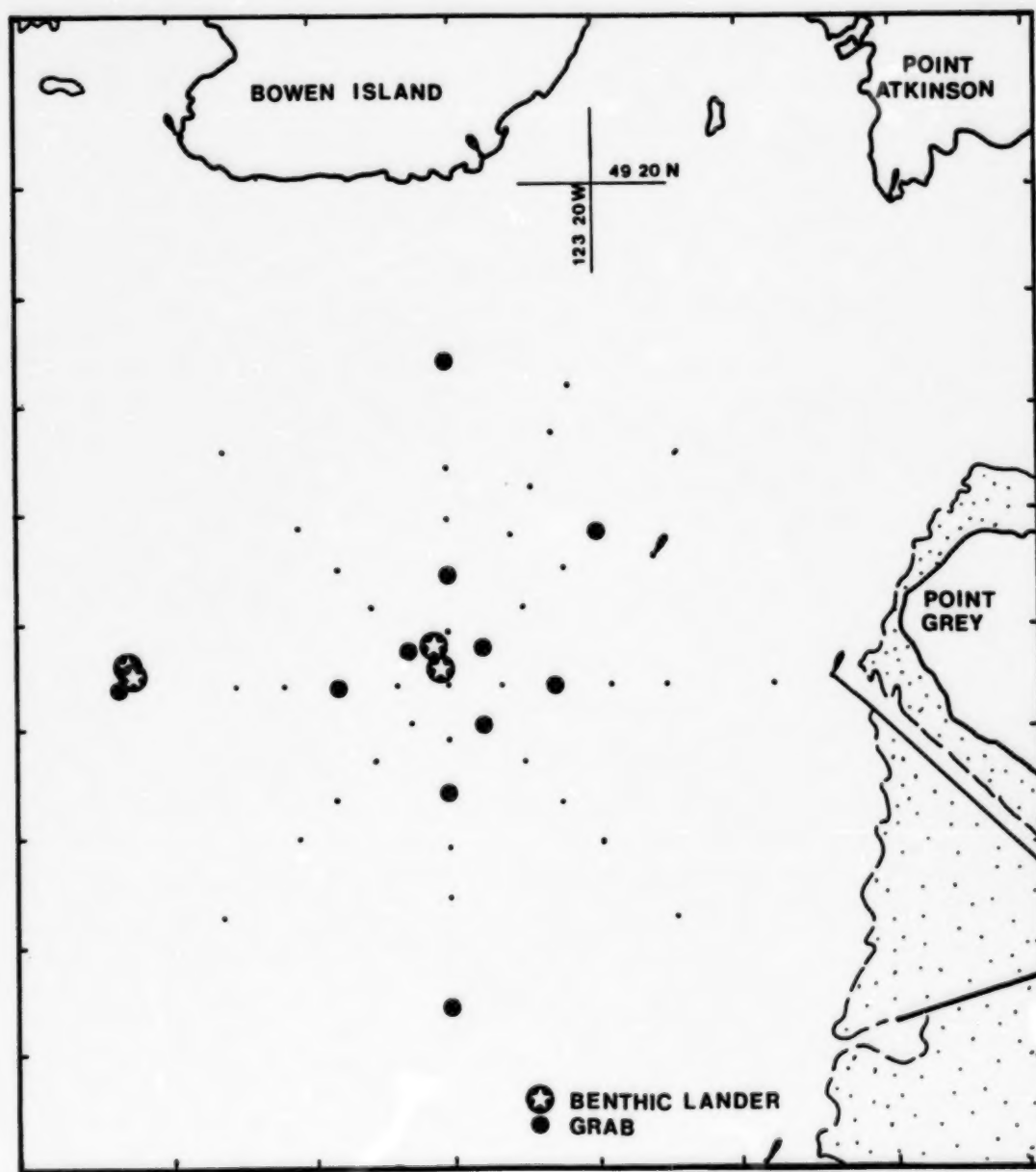


FIGURE 5.1 Chart of sampling stations at the Point Grey dumpsite.

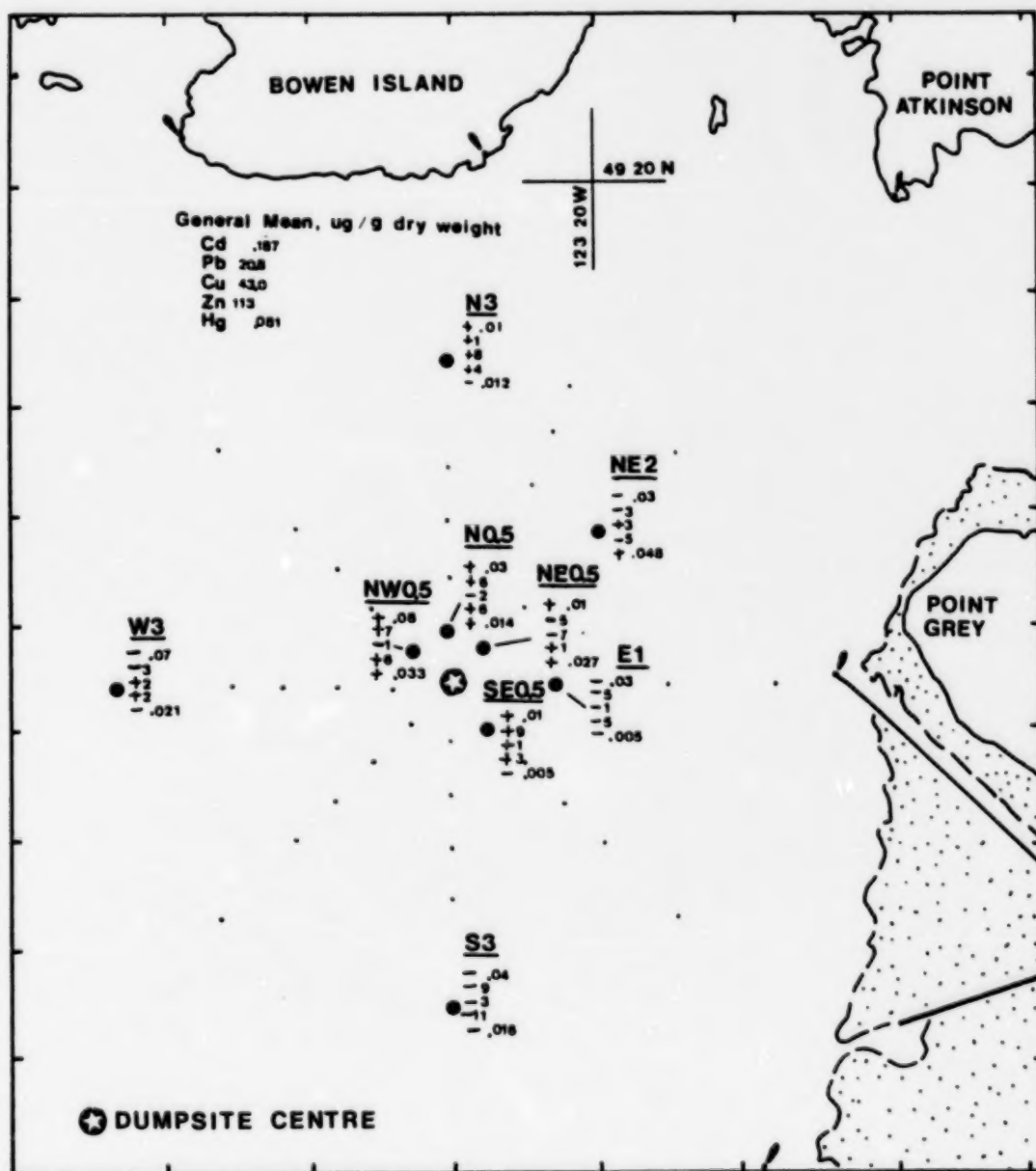


FIGURE 5.2 Heavy-metal concentrations in sediments at Point Grey dumpsite, March 1986.

6. COMPILATION AND ASSESSMENT OF RESEARCH, MONITORING AND DUMPING INFORMATION FOR ACTIVE DUMPSITES ON THE BRITISH COLUMBIA AND YUKON COASTS FROM 1979 TO 1987.

D.L. Sullivan

Contractor: D.L. Sullivan

Scientific Authorities: M. Waldichuk, DFO West Vancouver, and
R. Kussat, EPS West Vancouver

Conservation and Protection (Environment Canada) has administered the requirements of the Ocean Dumping Control Act in the Pacific and Yukon Region since 13 December 1975.

A permit system was instituted to regulate the deliberate disposal of any substance from ships, aircraft, platforms and other man-made structures at sea and the disposal of substances considered harmful to the marine environment under special circumstances. Activities covered under the Act include experimental oil spills and stockpiling of construction aggregates in a submarine location.

The Act does not apply to: disposal that is incidental to or derived from the normal operations of a ship or aircraft or of any equipment thereof; any discharge that is incidental to or derived from the exploration for, exploitation of, and associated off-shore processing of sea bed mineral resources; fuel dumping from aircraft; disposal into the sea from land-based structures or outfalls; and the use of oil dispersants in environmental emergencies. A permit is not required when materials are placed in the sea for construction purposes, i.e., breakwaters, foreshore extension projects. Sidecast dredging during trench construction or burial of pipes or cables, etc., may not require a permit under the ODCA if environmental concerns have been addressed under another licence or approval system.

In January 1984, the B.C. Court of Appeal found that Section 4(1) of the Ocean Dumping Control Act was ultra vires of the federal parliament. The Court ruled that the disposal of substances into provincial marine waters was beyond the jurisdiction of the federal government. This ruling was partly based on the apparent lack of a linkage between ocean dumping and the authoritative powers given the federal government in provincial waters. These powers come under the heads of Navigation and Shipping, and Seacoast and Inland Fisheries. The B.C. court ruling has been appealed to the Supreme Court of Canada. A ruling from this Court is expected sometime in 1987¹. In the interim,

¹ On 4 March 1988 the Supreme Court ruled in favour of the Federal Government, indicating that Section 4(1) of the Ocean Dumping Control Act is constitutionally valid in B.C. marine waters.

requirements of the Ocean Dumping Control Act that relate to the protection of fish, fish habitat and man's use of fish are being administered under the authority of Subsection 33.1(1) of the Fisheries Act. Until such time as the Supreme Court ruling is handed down, the Pacific and Yukon Region administration office continues 'business as usual' with the exception that 'Approvals' are issued, rather than formal 'Permits' which have to appear in the Canada Gazette before becoming valid.

A review of historical and existing ocean dumping activity in the Pacific Region was compiled in 1980 (Ward and Sullivan, 1980). The report prepared under this contract (Sullivan, 1987) is a continuation of that review and includes all available information on ocean dumping incidents occurring from 1 January 1980 to 1 January 1987 occurring at dumpsites on the British Columbia and Yukon coasts. Unless otherwise noted, the material discharged was dredged material consisting of wood, wood debris, sand, silt, gravel, mud, etc. Where available, details on research and monitoring studies conducted at the dumpsites are provided.

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7. SOME HIGHLIGHTS OF THE SEVENTH INTERNATIONAL OCEAN DISPOSAL SYMPOSIUM, WOLFVILLE, NOVA SCOTIA, 21-25 SEPTEMBER 1987

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Being held for the first time in Canada, this International Symposium was attended by about 110 people from 19 countries, but predominantly from the USA (58%) and Canada (27%). It was supported by the Nova Scotia Dept. of Environment, Environment Canada, U.S. Army Corps of Engineers, U.S. National Oceanic and Atmospheric Administration, U.S. Environmental Protection Agency, World Bank, International Maritime Organization and United Nations Environment Programme. Travel funds for persons attending from developing countries were provided by the latter three international organizations. Dr. Scott MacKnight of the OceanChem Group, Dartmouth, N.S., who was co-chairman of the Symposium, and who made all of the local arrangements with the help of his local organizing committee, derived some support from a contract under the Ocean Dumping Control Act Research Fund.

The papers were presented in eight sessions: (1) Industrial Waste and Sewage Sludge in the Oceans; (2) Ocean Outfalls; (3) Dredged Material Disposal; (4) Management of Wastes in the Ocean; (5) Pathways and Fates of Wastes in Marine Environments; (6) Biological Effects; (7) Incineration at Sea; and (8) Risk Assessment in Marine Waste Management. There was also a poster session. As in previous symposia, there were three special speakers [John Karau: Ocean Disposal in Canada; Robert Lazor: Overview of the Interagency Testing of Dredged Material Field Verification Program (FVP); and H. Compaan: Environmental Acceptability of Ocean Incineration Emissions and Some Remarks on Future Research and Regulations]. There were also two keynote speakers in the regular sessions (C.R. Lee: Decision-Making Framework for Dredged-Material Management; and Patrick McLaren: Using Sediments to Predict Dispersal of Contaminants) and a banquet keynote speaker (R. Boelans: Justifying Sea Disposal of Wastes).

A few highlights of the presentations follow. Several papers continued to give results of experiments with artificial reefs off the coast of Florida, made up of blocks of coal ash and oil-combustion residues. These blocks colonized rapidly (within 5 months) by seaweeds, invertebrates and fish. A concern was the release of metals into seawater, particularly vanadium from oil-combustion residues. A "bouquet" was extended to the National Research Council of Canada for its seawater reference material

(NASS-1), which they found very useful in their analysis of seawater. There was no evidence of enrichment of metals in organisms on the artificial reefs.

In 1985, the 12-mile sewage sludge dumpsite in the New York Bight was essentially closed, after 60 years of dumping, and sludge disposal was shifted to the 106-mile dumpsite. To document the changes during and following the planned phaseout and cessation of dumping in December 1987, surveys were begun with 25 stations in and around the dumpsite in July 1986. Variables being measured include: water and sediment chemistry; benthic community structure; distribution, abundance, gross pathology and food habits of fish and invertebrates; body burdens of selected contaminants; and microbial contamination of shellfish and sediment. Migration patterns of winter flounder are being determined by tagging. It is too early to report results, but some working hypotheses are: (1) bacteria from sewage in shellfish will decline, allowing shellfish beds to be opened; (2) diets of selected species, including lobster and winter flounder will change as a result of shifts in benthic forage species; and (3) the distribution and density of Capitella sp. will be reduced at certain stations.

A good series of presentations was given on dredged-material disposal, particularly on research results from the Dredged Material Field Verification Program, conducted jointly by the U.S. Army Corps of Engineers and the U.S. Environmental Protection Agency from 1982 to 1987. This research is being done on material obtained in Black Rock Harbor, near Bridgeport, Conn., which has been described as having the consistency and appearance of black mayonnaise and being highly contaminated. Different strategies for disposal of this material are being evaluated using (1) aquatic, (2) wetland and (3) upland sites. The biological responses being measured in aquatic and wetland sites include: bioaccumulation, scope for growth, bioenergetics, adenylate energy charge, sister chromatid exchange, histopathology, survival, growth, reproduction, population growth rate, recolonization and community structure.

Field verification was conducted on the indigenous infaunal polychaete, Nephtys incisa, and the introduced mussel, Mytilus edulis. The hypothesis being tested was that exposure-response relationships developed in the laboratory were not significantly different from those determined in the field. The bioaccumulation of PCB and PAH contaminant classes, their chemical patterns, and magnitude of bioaccumulation in M. edulis and N. incisa were comparable in field and laboratory. Measures of scope for growth and shell growth in M. edulis, and for respiration, excretion and histopathology in N. incisa in the laboratory and the field showed

excellent correspondence for comparable exposures. Adenylate energy charge and sister chromatid exchange were not field verifiable. It was recommended on the basis of these studies that measures of survival, growth, reproduction, population growth, scope for growth, bioenergetics, and bioaccumulation can be used in pre-disposal evaluations of dredged material.

There was an interesting session on incineration at sea. The talk given by H. Compaan was particularly convincing on the advantages of incineration of organochlorines at sea over incineration on land or other means of disposal. Although he said that objection to incineration at sea exists mainly in North America, he had to admit on questioning that the Nordic countries in Europe also object to incineration at sea and are pressing in international fora, such as the London Dumping Convention, to have it phased out by 1992.

Radioactive waste disposal in the sea was discussed in three papers, two by U.S. authors and one by a French participant, even though such disposal has been kept in a low key, especially since the Chernobyl incident. A Seabed Working Group is functioning under the aegis of the European Nuclear Energy Agency with a budget of about \$20 M to examine ocean sites for disposal of high-level radioactive wastes. Areas near subduction zones are being examined for this purpose. In the Atlantic, a site west of the Strait of Gibraltar and one east of the Caribbean are being closely scrutinized. A site east of southern Japan and south of Kamchatka in the Pacific appears to be attractive for experiments on suitability for high-level radioactive waste disposal.

A Canadian East Coast paper that might have relevance in British Columbia dealt with "Reduction and resolution of conflicts between ocean dumping and aquaculture". Potential conflicts between ocean dumping and aquaculture arose from a dredge-spoil sediment plume allegedly impacting a mussel farming operation. Resuspension of contaminants and faecal coliforms has been raised as an issue. A computer-based system used to identify potential conflicts during the permit application process has been developed. The geographic coordinates of a proposed project can be used to search a complementary data base for activities, falling within a variable-sized quadrant, which could conflict with the proposal.

On the subject of risk assessment, there was an interesting paper on relative risks of Great Lakes contaminants. The author noted that sportsfishermen are catching great quantities of contaminated salmon and consuming them. What are the health risks to the consumers? He noted that the biological endpoint must be the same when comparing risks, i.e., cancer risks cannot be compared with acute risks. There is much uncertainty in risk assessment and this uncertainty, which is rarely quantified, is

difficult to communicate to the public. It is important to differentiate perceived risk from real risk. He concluded that eating Great Lakes fish is the most likely route for carcinogenic substances from the Great Lakes reaching humans. By comparison, drinking Niagara River water would pose a very much lower cancer risk.

Most of the papers from the Seventh International Ocean Disposal Symposium will be published in Proceedings processed by Dr. MacKnight and Environment Canada. Selected papers, dealing with options for waste disposal at sea, e.g., incineration and artificial reefs, will likely be published in a special issue of the Marine Pollution Bulletin.

The Eighth International Ocean Disposal Symposium is being considered for Dubrovnik, Yugoslavia, in the fall of 1989.

8. POLLUTION OF THE WEST COAST OF THE UNITED STATES: A
PERSPECTIVE FOR THE FUTURE

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Pacific Northwest Research Foundation
Seattle, WA

Recent studies of pollution-related problems in San Diego, San Francisco, Los Angeles and Seattle/Tacoma have revealed a variety of toxic chemicals in sediments and certain marine species. Additional evidence has shown that pathological conditions in fish are associated with exposure to the toxic chemicals in some areas (Malins et al, 1987a; Malins et al, 1987b).

While each of the West Coast areas has not been studied extensively or to the same degree, significantly different proportions of toxic chemicals were identified in the areas studied. For example, concentrations of DDT and derivatives were high in sediments and biota from the vicinity of Los Angeles compared to the values obtained from the other areas (Malins et al. 1987b; McCain et al, 1988).

Pollution-related pathological conditions (liver lesions and fin erosion) were found in bottom-feeding fish from Los Angeles, San Diego and Seattle/Tacoma, often in relatively high prevalences (Malins et al, 1987a; Malins et al, 1987b; McCain et al, 1988).

Studies of 46 sampling sites in Puget Sound (Malins et al, 1987b; McCain et al, 1988) have provided evidence for an association between toxic chemicals (e.g., aromatic hydrocarbons) and neoplastic and "pre-neoplastic" liver lesions in bottomfish; however, no such evidence has been provided for the other West Coast areas. Clearly, these gaps in knowledge need to be filled. However, there are inherent limitations to the information that can be obtained from these types of studies. While the data may suggest possible cause/effect relationships between chemical exposures and biological effects in the field, they fall short of actually establishing such relationships. In addition, a number of acute bioassays, employed in the study of toxicity of sediments and water, are increasingly being criticized. The criticisms range from the validity of the tests (e.g., positive results on "clean" sediments) to the relevance in demonstrating effects on complex ecosystems. To add to these problems, few chronic bioassays have been routinely applied in studying the important issue of long-term effects.

As a consequence of these deficiencies, the assessment of environmental damage from low levels of toxic chemicals in rivers, estuaries and bays is severely hampered. What is especially needed is a programme to develop new, innovative methods for the assessment of chronic effects.

It is suggested that biomarker techniques involving the assessment of "DNA damage" and bioassays that focus on the life cycles of key ecosystem components are steps in the right direction.

In conclusion, it seems that if we do not solve the problems mentioned, we will never really come to grips with the complex pollution issues that will be with us for decades, and which will most probably increase in severity with population expansion and industrial development.

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APPENDIX 1

LOCATIONS OF PARTICIPANTS IN 1987

I. GOVERNMENT

DFO - Department of Fisheries and Oceans:

IOS - Institute of Ocean Sciences

P.O. Box 6000

SIDNEY, B.C. V8L 4B2

WVL - West Vancouver Laboratory

4160 Marine Drive

WEST VANCOUVER, B.C. V7V 1N6

Environment Canada:

EPS - Environmental Protection Service

Aquatic Toxicity Laboratory

1801 Welch Street

NORTH VANCOUVER, B.C. V7P 1B7

and

Kapilano 100, Park Royal South

WEST VANCOUVER, B.C. V7T 1A2

Public Works Canada:

1166 Alberni Street

VANCOUVER, B.C. V6E 3W5

Ministry of Environment and Parks, British Columbia:

Planning and Assessment Branch

3rd Floor, 777 Broughton Street

VICTORIA, B.C. V8V 1X5

Waste Management Branch

2560 Kenilworth Road

NANAIMO, B.C. V9T 2H7

and

15326 103A Avenue

SURREY, B.C. V3R 7A2

and

810 Blanshard Street

VICTORIA, B.C. V8V 1X5

CRD - Capital Regional District:
 Engineering Services
 Wastewater Division
 P.O. Box 1000
 524 Yates Street
 VICTORIA, B.C. V8W 2S6

II. INDUSTRY

AMAX of Canada Limited
 Box 12525 Oceanic Plaza
 Suite 1600 - 1066 West Hastings
 VANCOUVER, B.C. V6E 3X1

AQUAMETRIX Research Limited
 Suite 204 - Seaside Plaza
 2527 Beacon Avenue
 SIDNEY, B.C. V8L 1Y1

Aquatic Science Consultants Limited
 239 Chambers Place, R.R. #3
 Site B, C-6
 NANAIMO, B.C. V9R 5K3

ARCPAC Consulting Services
 11368 West Saanich Road, R.R. #3
 SIDNEY, B.C. V8L 3X9

CAN TEST Limited
 1523 West 3rd Avenue
 VANCOUVER, B.C. V6J 1J8

Castor Consultants Limited
 106 - 1338 W. 10th Avenue
 VANCOUVER, B.C. V6H 1J6

CBR International Corporation
 P.O. Box 2010
 9865 West Saanich Road
 SIDNEY, B.C. V8L 3S3

COASTLINE Environmental Services Limited
 2377 West 8th
 VANCOUVER, B.C. V6K 2A8

Edward Anderson Marine Sciences
 P.O. Box 2125
 2035 Mills Road
 SIDNEY, B.C. V8L 3S6

E.V.S. Consultants Limited
195 Pemberton Avenue
NORTH VANCOUVER, B.C. V7P 2R4

Plumper Ocean Projects
319 Stewart Avenue
VICTORIA, B.C. V9B 1R6

Seakem Oceanography Limited
2045 Mills Road
SIDNEY, B.C. V8L 3S1

S.M. Woods Consulting
9332 Webster Place
SIDNEY, B.C. V8L 2S1

III. UNIVERSITY

Department of Oceanography
University of British Columbia
VANCOUVER, B.C. V6T 1W5

IV. RESEARCH FOUNDATION

Pacific Northwest Research Foundation
1102 Columbia Street
SEATTLE, WA 98104

APPENDIX II

OCEAN DUMPING WORKSHOP ATTENDANCE LIST

E.P. Anderson, Edward Anderson Marine Sciences, Sidney, B.C.
(604-656-6434)

D. Brothers, EPS, Ocean Dumping Section, West Vancouver, B.C.
(604-666-2990)

J.P. Campbell, AMAX of Canada Ltd., Vancouver, B.C. (604-689-0541)

M. Clark, Ministry of Environment and Parks, Waste Management
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B. Imber, CBR International Corp., Sidney, B.C. (604-655-1944)

C. Kingman, Public Works Canada (Pacific), Vancouver, B.C.
(604-666-6782)

R. Kussat, EPS, Ocean Dumping and Contaminants Control, West
Vancouver, B.C. (604-666-3601)

R. Langford, Ministry of Environment and Parks, Planning and
Assessment Branch, Victoria, B.C. (604-387-9675)

- D.C. Malins, Pacific Northwest Research Foundation, Seattle,
Washington, U.S.A. (206-292-7545)
- J. Morgan, E.V.S. Consultants Ltd., Vancouver, B.C. (604-986-4331)
- D. Moul, EPS, Aquatic Toxicity Laboratory, North Vancouver, B.C.
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- R.W. Macdonald, DFO/IOS, Ocean Chemistry, Sidney, B.C.
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R.R. #7, Victoria, B.C. V8X 3X3 (604-479-3828)
- E.R. McGreer, COASTLINE Environmental Services Ltd., Vancouver,
B.C. (604-688-1326)
- J. McNee, University of British Columbia, Vancouver, B.C.
(604-228-3278)
- H. Nelson, EPS, West Vancouver, B.C. (604-666-2947)
- R. Pym, CRD, Engineering Services, Victoria, B.C. (604-386-1669)
- B. Reid, 4825A Drummond Dr., Vancouver, B.C. V6T 1B5
(604-666-0129)
- I.H. Rogers, DFO/WVL, West Vancouver, B.C. (604-666-7912)
- C. Ruiz, University of British Columbia, Vancouver, B.C.
(604-228-3278)
- N. Russo, Ministry of Environment and Parks, Waste Management
Branch, Victoria, B.C. (604-584-8822)
- D. Thomas, Seakem Oceanography, Sidney, B.C. (604-656-0881)
- J.A.J. Thompson, DFO/IOS, Ocean Chemistry, Sidney, B.C.
(604-356-6408)
- D. Timuss, CAN TEST Ltd., Vancouver, B.C. (604-734-7276)
- I. Torrie, University of British Columbia, Vancouver, B.C.
(604-228-3278)
- M. Waldichuk, DFO/WVL, West Vancouver, B.C. (604-666-7930)
- R. Waters, Castor Consultants Ltd., Vancouver, B.C. (604-731-8760)

R.G. Watts, EPS, Aquatic Toxicity Laboratory, North Vancouver, B.C.
(604-666-6247)

R. Wilson, DFO/IOS, Data Assessment Division, Sidney, B.C.
(604-356-6335)

C.S. Wong, DFO/IOS, Ocean Chemistry, Sidney, B.C. (604-356-6407)

S.M. Woods, S.M. Woods Consulting, Sidney, B.C. (604-656-3597)

S. Yee, EPS, Aquatic Toxicity Laboratory, North Vancouver, B.C.
(604-666-6247)

M. Yunker, DFO/IOS, Ocean Chemistry, Sidney, B.C. (604-356-6411)

APPENDIX III

1986-1987 CONTRACTS
PACIFIC REGION

1. Sediment toxicity tests to address the effects of ocean-dumped material on fertilized eggs of a commercially-important fish species. \$16,000

Scientific Authority: M. Waldichuk, DFO/WVL
Contractor: COASTLINE Environmental Services Limited
SSC File No.: 06SB.FP941-6-0897
2. Compilation and assessment of research monitoring and dumping information for active dumpsites on the B.C. coast from 1979 to 1986. \$ 5,000

Scientific Authorities: M. Waldichuk, DFO/WVL,
and R. Kussat, EPS,
West Vancouver
Contractor: D.L. Sullivan
SSC File No.: 09SB.KE603-6-0644
3. An assessment of the distribution of cadmium in marine sediments. A core study of elevated cadmium levels in Ucluelet Inlet, B.C. \$17,300

Scientific Authority: H. Nelson, EPS,
West Vancouver
Contractor: R. Waters
SSC File No.: 09SB.KE603-6-0166
4. Effects of suspended silt on eggs and larvae of three commercially-important fish species in the Strait of Georgia. \$17,325

Scientific Authority: C. Levings, DFO/WVL
Contractor: E.V.S. Consultants Limited
SSC File No.: 06SB.FP941-6-1940

5. Organization of west coast ocean dumping workshop and preparation of workshop proceedings for publication.

\$ 4,050

Scientific Authority: R. Wilson, DFO/IOS
Contractor: S.M. Woods Consulting
SSC File No.: 06SB.FP941-6-1899

APPENDIX IV

1987-1988 CONTRACTS
PACIFIC REGION

1. Sediment transport regime at the Point Grey
dumpsite: implications for the dispersal of
contaminants and waste disposal monitoring. \$35,000

Scientific Authority: R. Macdonald, DFO/IOS
Contractor: Seakem Oceanography Limited
SSC File No.: 06SB.FP941-7-1159
2. Amphipod bioassays on sediment along the B.C.
coast containing heavy metals and organic
sediments. \$18,766

Scientific Authority: M. Waldichuk, DFO/IOS
Contractor: E.V.S. Consultants Limited
SSC File No.: 06SB.FP941-7-1088
3. Demonstration and field testing of a remote
deep-ocean retrieval system for use in
environmental fate and effects studies at
ocean dumpsites. \$15,000

Scientific Authority: C. Levings, DFO/WVL
Contractor: COASTLINE Environmental Services
Limited
SSC File No.: 06SB.FP941-7-1186
4. Preparation of the West Coast ocean dumping
workshop. \$4,050

Scientific Authority: R. Wilson, DFO/IOS
Contractor: S.M. Woods Consulting
SSC File No.: 06SB.FP941-7-7142